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Finite Element Analysis of Rectangular Fin Array

B.Hemasunder[1*], M Radhika[1]

[1]*Assistant Professor, Dept of Mechanical Engg, Jayamukhi Institute of Technological Sciences, Warangal, India*

**Corresponding author E-Mail ID: hms.worlds@gmail.com, Mobile: 9030607332*

ABSTRACT

In this paper Thermal, CFD analysis is conducted on the rectangular fin arrays by natural convection heat transfer process. Parameters varied in this work are space length, and thickness of fins. Circular, Elliptical pin fin and Rectangular pin fins are compared for better heat transfer rate. Different materials Copper and Aluminum are considered for fins. 3D modeling software Pro/Engineer is used for 3D models. Thermal and CFD analysis is performed in Ansys software.

1. INTRODUCTION

Electronics devices and equipment now permeate virtually every aspect of our daily life. Among the most ubiquitous of these is the electronic computer varying in size from the hand held personal digital assistant to large scale main frames or servers. In many instances a computer is embedded within some other devices controlling its function and is not even recognizable as such. For example in automobiles, space crafts, missiles, satellite etc. The applications of computers vary from games for entertainment to highly complex systems supporting vital heath, economic, scientific, mobile phones, and defense activities. The dimensions of the instruments also decreasing day by day but simultaneously the number of functions increases as a result the functions per unit volume are increasing hugely, this is most visible in portable electronic component, such as laptops, cell phones, digital cameras and other items around us, where an increasing number of functional components are squeezed into an ever shrinking system box. Compact packaging is also in progress in desktop sand in server computers, driven by the needs to reduce the box dimensions and cut wiring distances between electronic devices. In a growing number of applications computer failure results in a major disruption of vital services and can even have life-threatening consequences. As a result, efforts to improve the reliability of electronic computers or electronics chips are as important as efforts to improve their speed and storage capacity.

1.1.Design Parameters of Heat Sink

The design parameters include the heat sink material, the number and geometry of the fins and their alignment and the base plate thickness. In order to obtain the minimum thermal resistance and pressure drop, each of these parameters must be designed well.

1.2.Heat Sink Material

Heat sinks are made from a good thermal conductor such as copper or aluminium alloy. Copper (401 W/m-K at 300 K) is significantly more expensive than aluminium (237 W/m-K at 300 K) but is roughly twice as efficient as thermal conductor. Aluminium has the significant advantage that it can be easily formed by extraction, thus making complex cross-sections possible. Aluminium is also much lighter than copper, offering less mechanical stress on delicate electronic components. Some heat sinks made from aluminium have a copper core. Although the thermal conductivity of zinc is lower compared to that of aluminum and copper, it may also be a good material for electronic cooling purposes. When zinc added to an alloy, it eliminates porosity in the casting process, which is an advantage over aluminum and copper since they are not pore free after the casting.

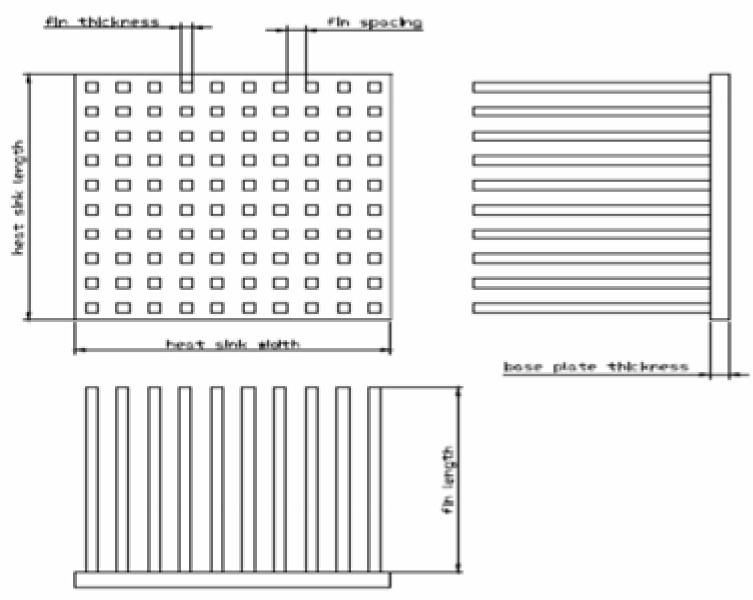


Fig 1 Heat sink design parameters

1.3.The Number of Fins

A heat sink usually consists of a base with one or more flat surfaces and an array of comb or fin-like protrusions to increase the heat sink's surface area contacting the air, and thus increasing the heat dissipation rate. It is one of the most important factors for heat sink performance. A heat sink designed for electronics cooling is a compact heat exchanger for which the ratio of heat transfer area to occupied volume is very large. Therefore increasing the number of fins provides more area for heat transfer. Increasing the number of fins from 238 to 294, increased the heat transfer area by 8.4 %. However, it should be noted that increasing the number of fins creates an adverse effect, which is the increased static pressure drop. In order to overcome higher pressure drops, higher pumping powers are needed, which requires the installation of more powerful fans or blowers.

1.4.Fin Shapes

Different kinds of heat sink geometries are possible. Pin fins (spines), uniform straight fins, tapered straight fins, splines and annular fins are possible. The most common ones are pin fins whose cross-section can be round, square, elliptical, hexagonal or any other suitable geometry.

2. LITERATURE REVIEW

In the paper by Michael E. Lyall [1], focuses on internal cooling of turbine airfoils using pin fins. Although the pin fins are not limited to a single shape, circular cross-sections are most common. The present study examines heat transfer from a single row of circular pin fins with the row oriented perpendicular to the flow. The configurations studied have span wise spacing to pin diameter ratios of two, four, and eight. Low aspect ratio pin fins were studied whereby the channel height to pin diameter was unity. The results show that the heat transfer augmentation relative to open channel flow is highest for the smallest span wise spacing for the lowest Reynolds number flows. The results also indicate that the pin fin heat transfer is higher than on the end wall. In the paper by V.S.Daund [2], Experimental and CFD analysis is conducted in order to establish effect of geometrical fin parameters for natural convection heat transfer from vertical rectangular fin arrays. It is found that convection heat transfer rate depends on fin height and fin length. For a given fin spacing, the convection heat transfer rate from fins increases with fin height. For a given fin spacing, the convection heat transfer rate from fins increases with fin length .This trend is observed for every fin configuration. It is found that convection heat transfer rate is more for less aspect ratio fin array for same power input. In the paper by Yasin Varol[3], a two-dimensional solution of natural convection in solid adiabatic thin fin attached to porous right triangular enclosures has been analyzed numerically. The vertical wall of the enclosure is insulated while the bottom and the inclined walls are isothermal. The temperature of the bottom wall is higher than the temperature of the inclined wall. Governing equations, which are written using Darcy model, are solved via the finite difference technique. The Successive Under Relaxation (SUR) method was used to solve linear algebraic equations. Dimensionless location of the thin fin from 0.2 to 0.6, the aspect ratio of triangular enclosure from 0.25 to 1, Rayleigh number from 100 to 1000 and the dimensionless height of the fin from 0.1 to 0.4 are used as governing parameters that are effective on heat transfer and fluid flow. Results for the mean Nusselt number, velocity profiles, the contour maps of the streamlines and isotherms are presented. It is observed that the thin fin can use as a passive control element for flow field, temperature distribution and heat transfer.

	LENGTH (mm)	WIDTH (mm)	THICKNESS (mm)
Original model	120	62	3
Modified model	100	62	2

3. DESIGN OF 3D-MODELS OF FINS

3D modeling of the fins without holes, circular holes, elliptical holes and rectangular holes for the given dimensions in the above table is done in Creo 2.0.

3.1.Original Model

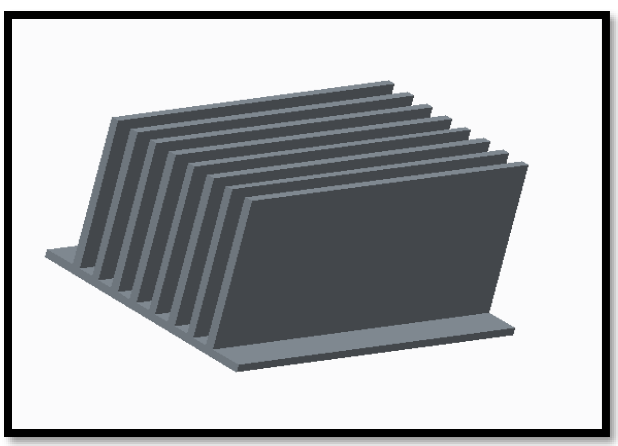


Fig 2 Solid Model

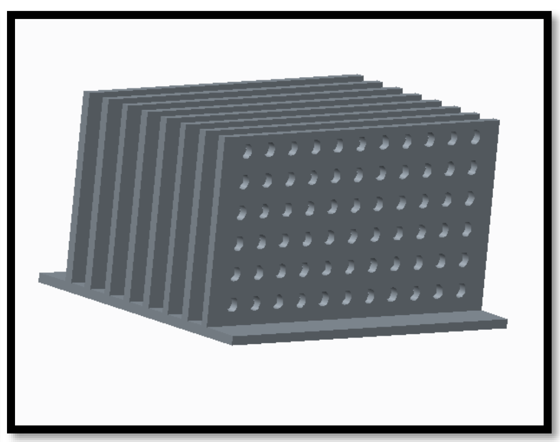


Fig 3 Circular Model

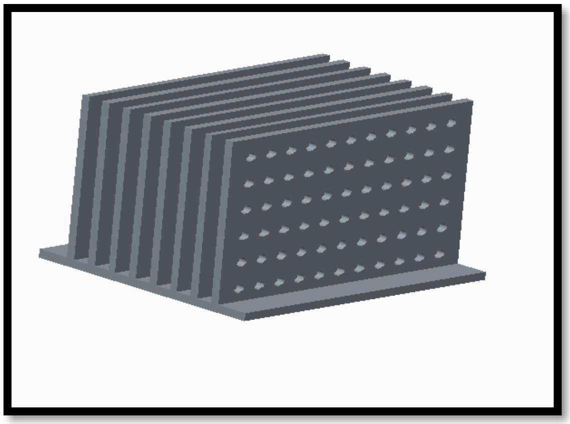


Fig 4 Elliptical model

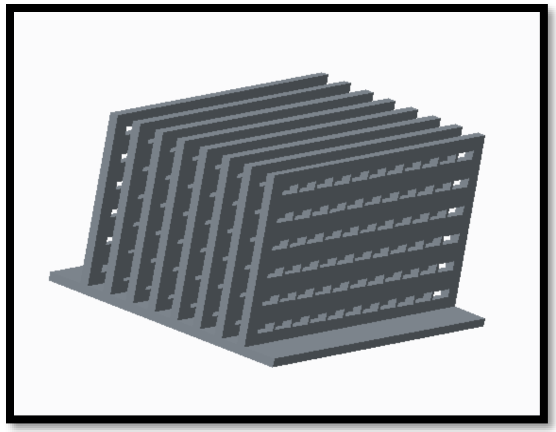


Fig 5 Rectangular model

4. CFD ANALYSIS OF FIN ARRAY

CFD analysis is done on all the models by taking air as fluid to determine the heat transfer coefficients, heat transfer rates, Reynold's number and Nusselt number, compared the results for better profile.

4.1. ORIGINAL MODEL SOLID FLUID –AIR

Enter Inlet Velocity → 4.5 m/s and Inlet Temperature – 343 K

4.1 Temperature

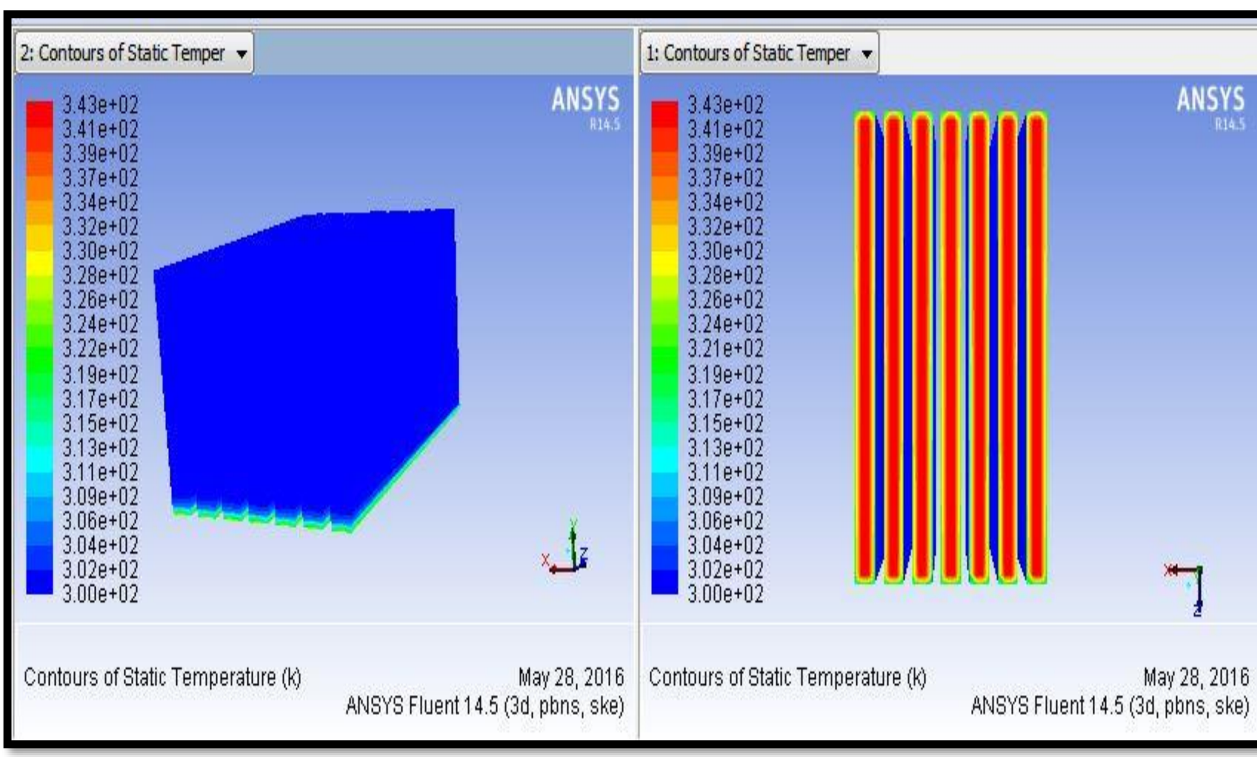


Fig 6

4.2 Nusselt number

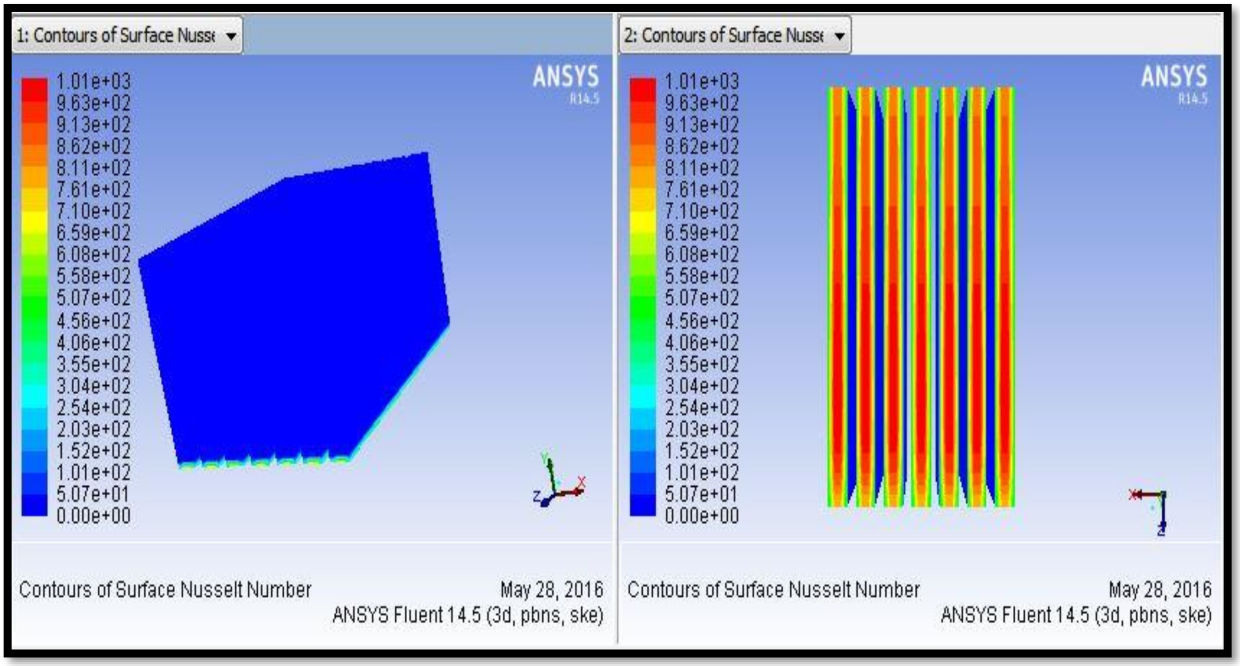


Fig 7

4.3 Reynolds number

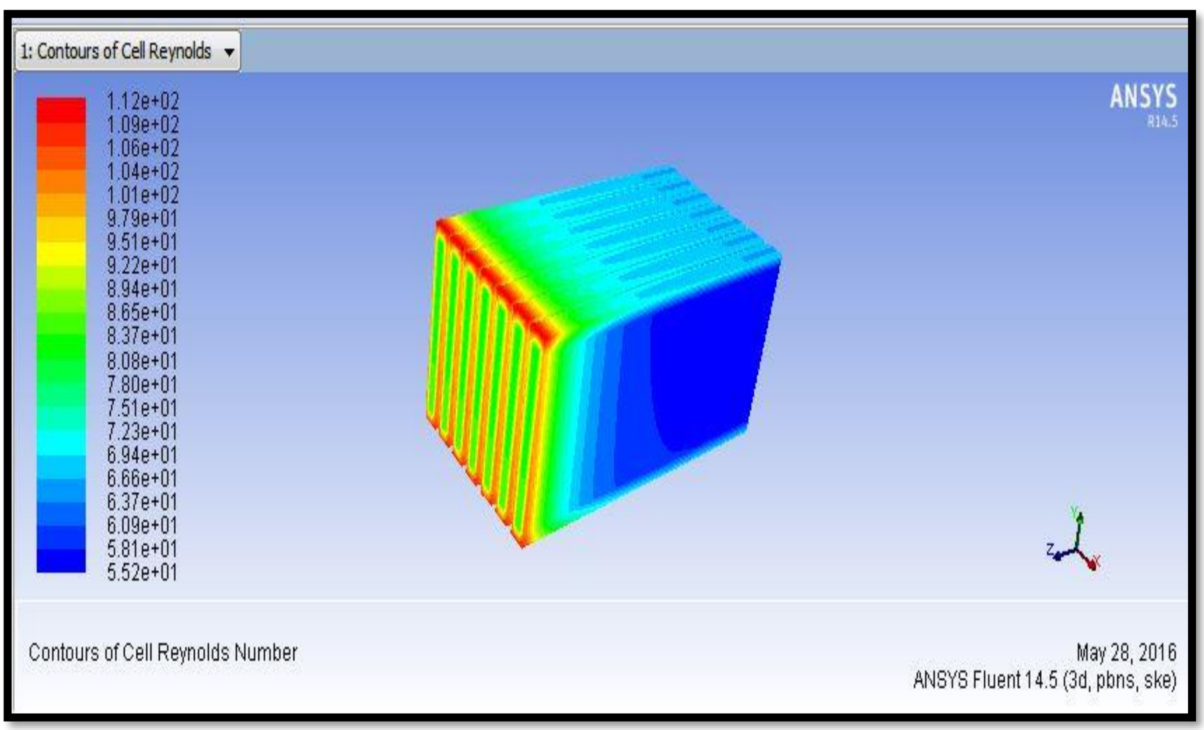


Fig 8

4.4 Heat transfer coefficient

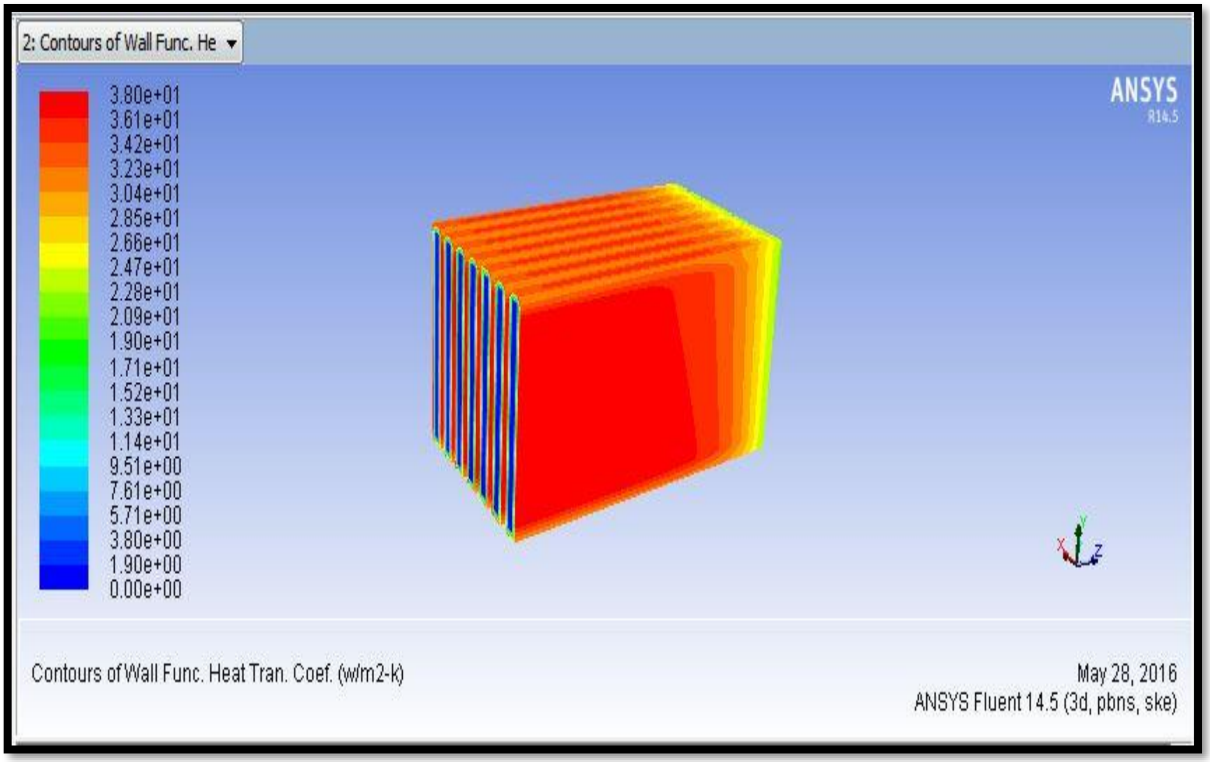


Fig 9

Total Heat Transfer Rate (w) Net 0.0095624924

5. THERMAL ANALYSIS OF FIN ARRAY

Heat transfer analysis is done on fin array using two materials Copper and Aluminum for heat sink to determine heat transfer rates.

5.1 Original solid model

Material properties of Copper

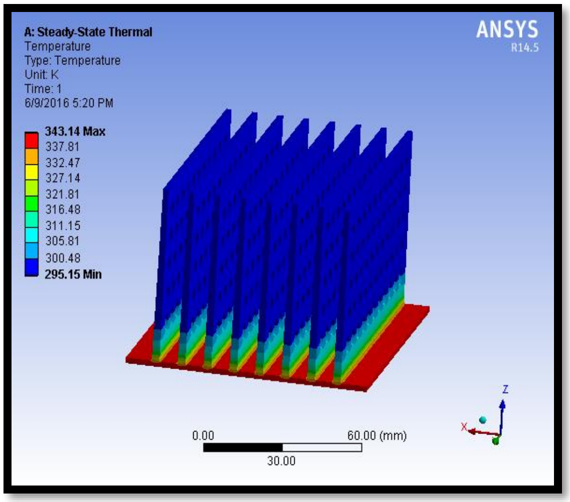
Thermal conductivity : 385 W/mK

Material properties of Aluminum

Thermal conductivity: 210 W/mK

5.2 Circular

Material – copper



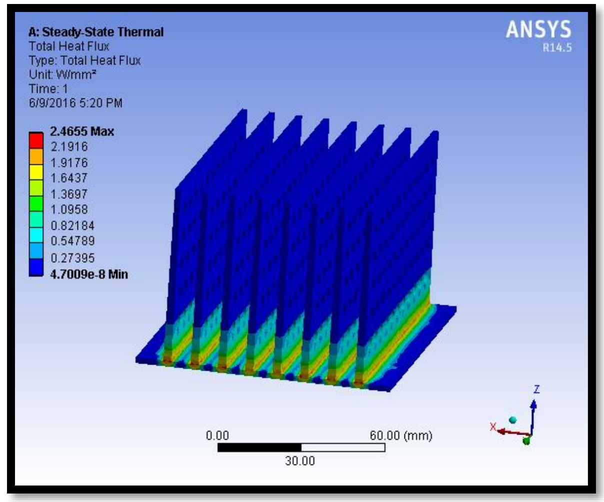


Fig 10 Temperature

Fig 11 Heat flux

6. RESULTS & DISCUSSIONS

6.1.CFD analysis results for original model

	Temperature (K)	Nusselt number	Reynolds number	Heat transfer coefficient (W/m^2-k)	Heat transfer rate (W)
Solid	3.43e+02	1.01e+03	1.12e+02	3.80e+01	0.0095624924
Circular	3.43e+02	2.41e+03	1.42e+02	2.56e+02	0.019176483
Elliptical	3.43e+02	2.37e+03	1.09e+02	9.25e+02	-0.21875477
Rectangular	3.43e+02	2.26e+03	1.11e+02	1.00e+02	0.029046059

6.2.CFD analysis results for modified model

	Temperature (K)	Nusselt number	Reynolds number	Heat transfer coefficient (W/m^2-k)	Heat transfer rate (W)
Solid	3.43e+02	4.99e+02	1.97e+03	1.69e+01	1.6733398
Circular	3.43e+02	1.04e+02	9.14e+03	1.01e+01	-7.5679016
Elliptical	3.43e+02	4.77e+02	2.20e+03	6.13e+01	4.7520752
Rectangular	3.43e+02	4.96e+02	8.94e+02	3.11e+01	-1.2069702

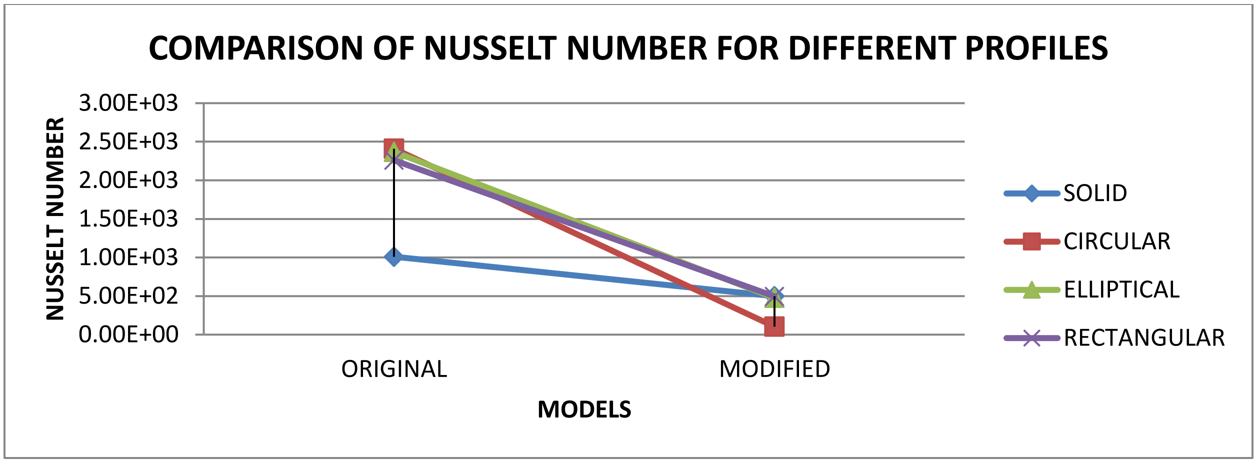


Fig 12

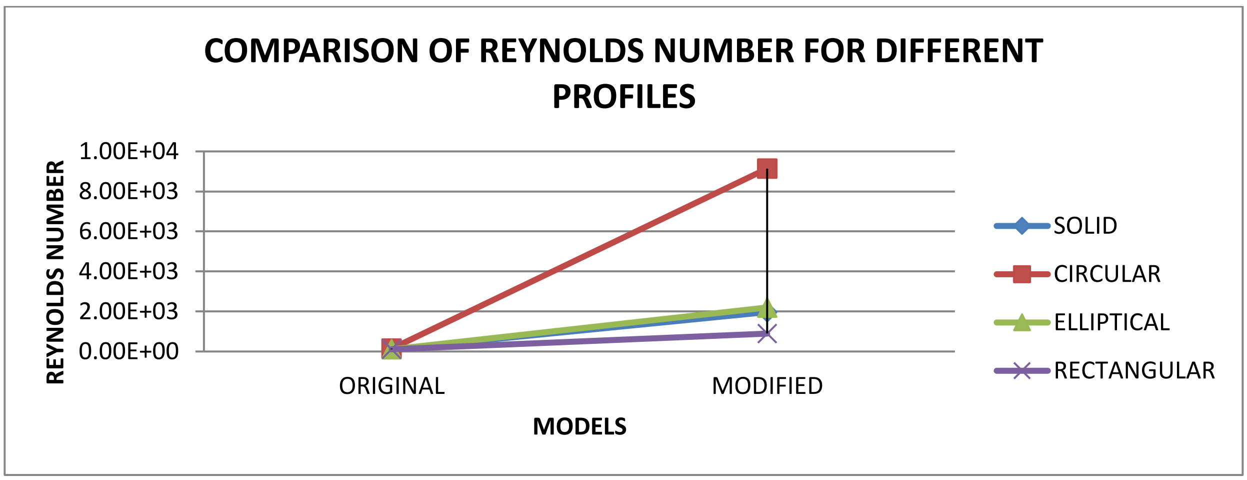


Fig 13

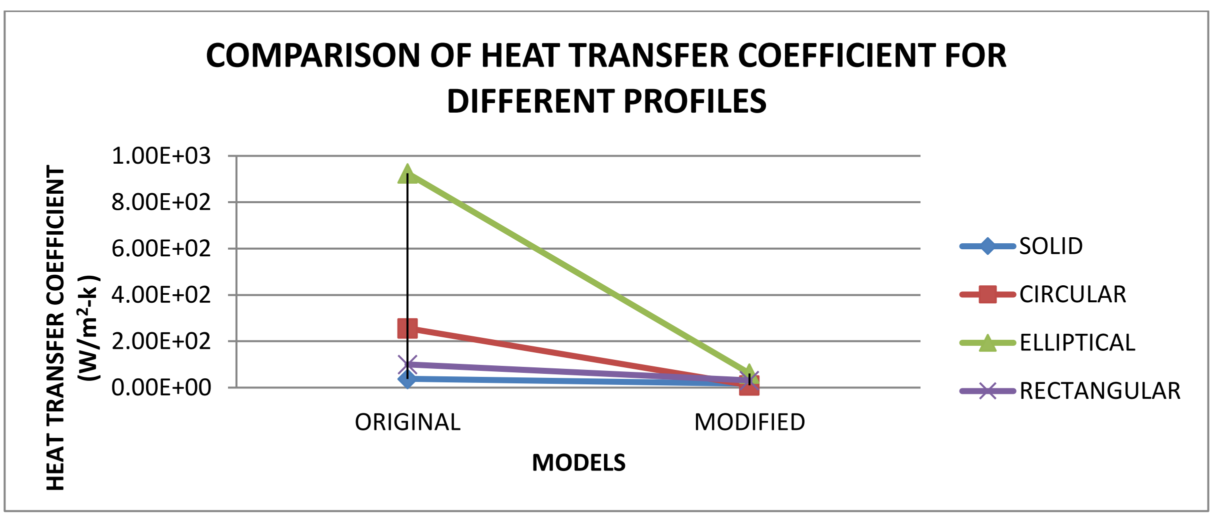


Fig 14

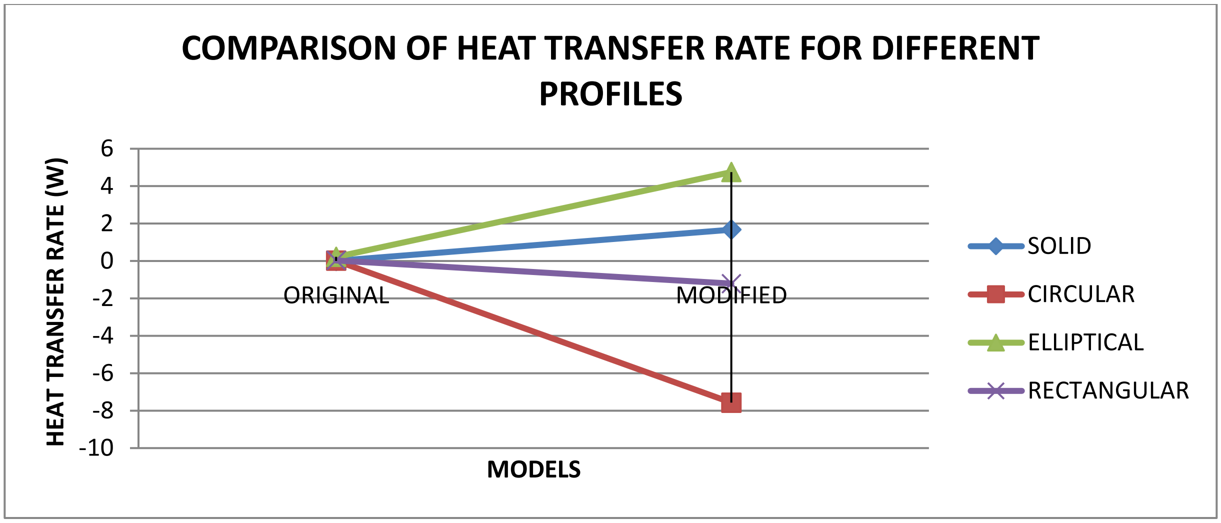


Fig 15

The above results determine that Nusselt number, Reynolds number, Total Surface Heat Flux and Heat transfer rate are increasing for the modified model than the original model. The results are more for Elliptical pin profile.

6.3.Thermal Analysis Results for Original Model

	Material	Temperature (K)	Heat flux(W/mm^2)
Solid	Copper	343	1.9709
	Aluminum	343	1.3758
Circular	Copper	343	2.4655
	Aluminum	343.18	1.7132
Elliptical	Copper	343.26	4.2288
	Aluminum	343.32	2.7846
Rectangular	Copper	343.07	1.9562
	Aluminum	343.1	1.1708

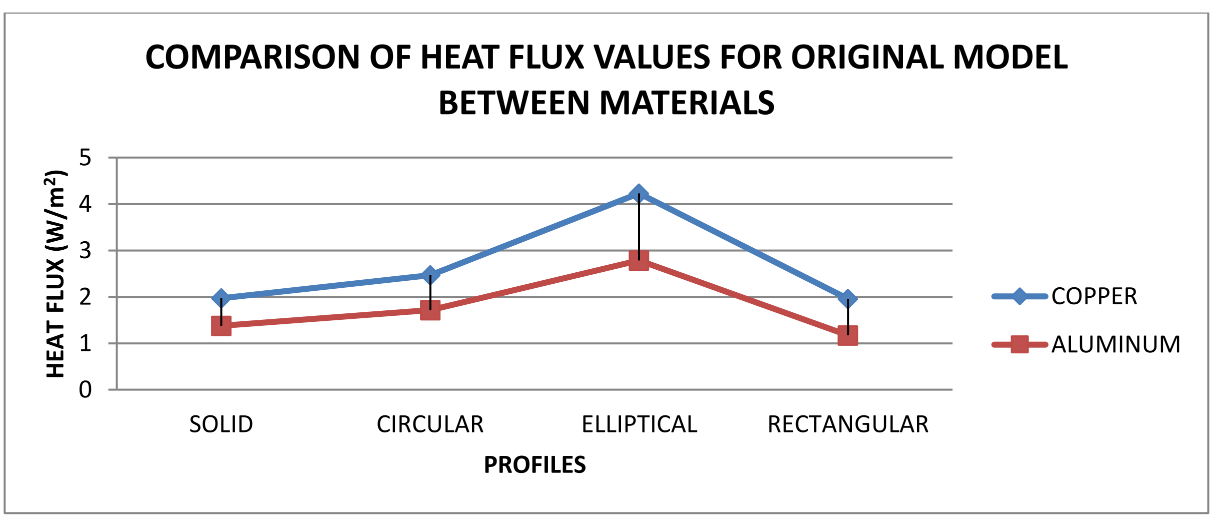


Fig 16

6.4.Thermal Analysis Results for Modified Model

	Material	Temperature (K)	Heat flux(W/mm^2)
Solid	**Copper**	343.01	1.4558
	Aluminum	343.01	1.0343
Circular	**Copper**	343.01	1.2278
	Aluminum	343.01	0.90593
Elliptical	**Copper**	343.02	2.7608
	Aluminum	343.02	1.9215
Rectangular	**Copper**	343.01	2.1469
	Aluminum	343.02	1.5189

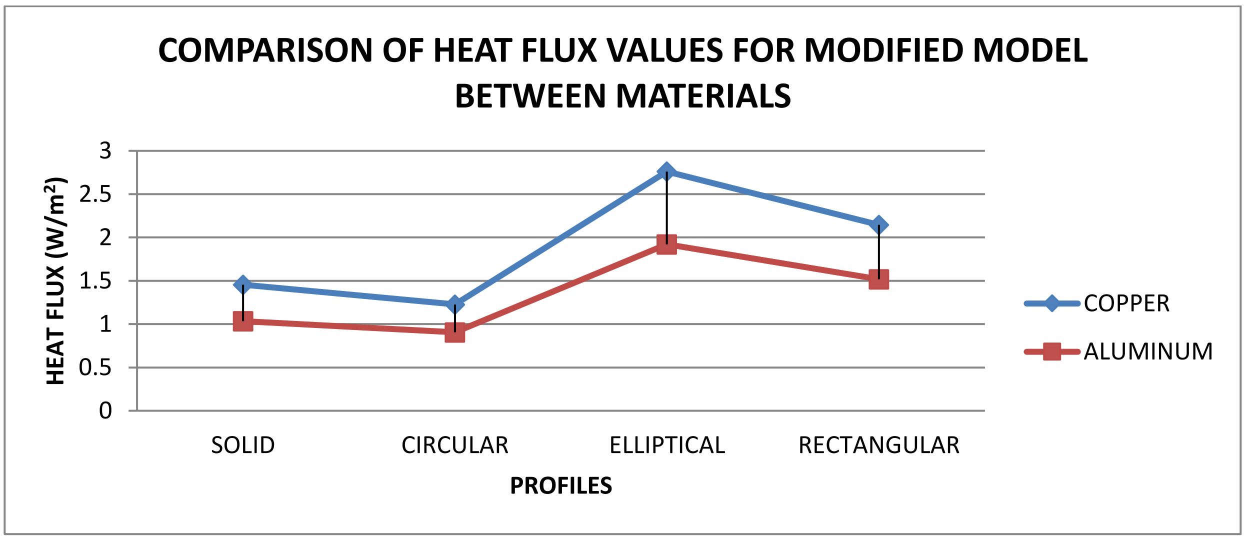


Fig 17

7. CONCLUSION

By observing CFD analysis results, Nusselt number, Reynolds number, Total Surface Heat Flux and Heat transfer rate are increasing for the modified model than the original model. The results are more for Elliptical pin profile. By observing thermal analysis results, the heat flux values are more for the modified model than the original model. That is the heat transfer rate is more. In the original model heat flux values are more for Elliptical and in the modified model heat flux values are more for Elliptical.

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